Multistatic, Concurrent Detection, Classification and Localization Concepts for Autonomous, Shallow Water Mine Counter Measures

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LONG-TERM GOALS

As a seamless vcontinuation of the previous SWAMSI grant, the objective continues to be the achievement of robust multi-static detection and classification of proud- and buried seabed objects using cooperative networks of autonomous vehicles with acoustic sources and receiving arrays.

OBJECTIVES

The emphasis of the MIT SWAMSI effort has focused on utilizing high fidelity acoustic modeling of both scatterers and shallow-water environments to better understand and bound the limits of detectability for mine-like objects via autonomous networks of sensors, and the assess the performance of time-reversal processing for concurrent detection, classification, localization and Tracking (DCLT) of seabed objects. The analysis s supported by series of experiments using multiple sonar-equipped AUVs in shallow water and then cross-validate the results obtained with high precision modeling and visualization. Another, related objective is to better understand the problems of cooperative autonomous vehicle interaction to define the base-line infrastructure requirements for cooperative detection, classification and navigation, an understanding which may lead to guidelines for optimal collaborative configuration control of the underwater sonar platforms.

APPROACH

This program couples high accuracy acoustic modeling and visualization with customized AUV technology. The sonar sensing uses the bi-static and multi-static Synthetic Aperture created by the network, in combination with medium frequency (4-24 kHz) wide-beam insonification to provide coverage, bottom penetration and location resolution for concurrent detection, localization and classification of proud and buried targets in SW and VSW. The signal processing effort in SWAMSI is therefore centered around generalizing SAS processing to bi-static and multi-static configurations, including bi-static generalizations of auto-focusing and track-before-detect (TBD) algorithms. Another

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14. ABSTRACT
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15. SUBJECT TERMS

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issue concerns the stability and coherence of surface and seabed multiples and their potential use in advanced medium-frequency sonar concepts.

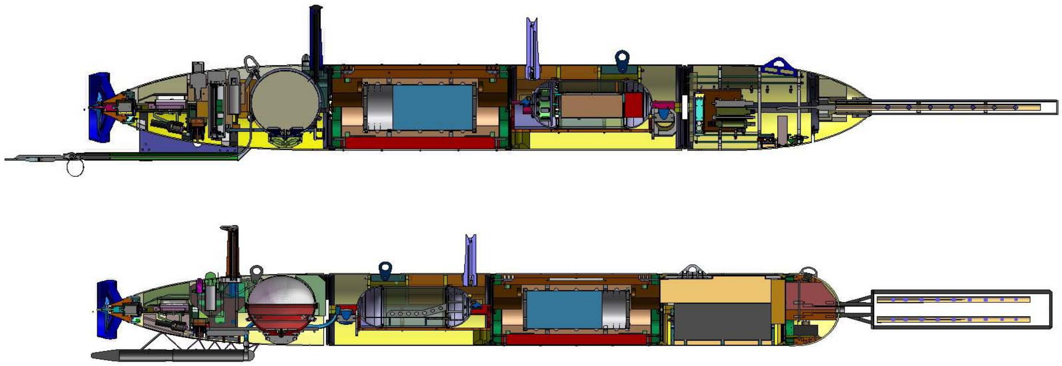
MIT's acoustic modeling capabilities derive from both the SEALAB suite (VASA Associates) for general shallow water acoustics and FEMLAB (COMSOL Inc) for detailed structural acoustics and target modeling. SEALAB incorporates the OASES environmental acoustic modeling framework developed at MIT [1,3], which is a widely distributed suite of models covering a variety of ocean waveguide and source/receiver representations. Recent developments are computational modules for full wave theory modeling of mono-static and bi-static target scattering and reverberation in shallow water waveguides. The most recently developed module, OASES-3D provides wave-theory modeling of the full 3-D acoustic environment associated with mono-static and bi-static configurations in SW and VSW with aspect-dependent targets and reverberation features [2,3]. It incorporates environmental acoustic features specifically associated with bi-static sonar concepts in shallow water, including aspect-dependent target models, seabed porosity, and scattering from anisotropic seabed roughness such as sand ripples.

With every major AUV deployment, the Mission Oriented Operating Suite (MOOS) previously created at MIT by research engineer Paul Newman advances in robustness and flexibility, and has been undergoing major upgrades in regard to the behavior-based control using the new IvP-Helm developed by Mike Benjamin of NUWC, who works closely with the MIT team as a Visiting Scientist. Another significant component is the development of a comprehensive simulation testbed, coupling the MOOS-IvP autonomous vehicle simulation environment with the SEALAB high-fidelity acoustic simulator, resulting in a complete, distributed software base for planning, simulating and analyzing multi-vehicle MCM missions.

WORK COMPLETED

Most of the effort under this Grant in 2008 has been devoted to the ppreparation for the SWAMSI'09 experiment in panama city, by re-configuring of the two MIT BF21 AUVs to the multistatic MCM configurations used in the FAF04 experiment, but with the previous sub-bottom profiler sources replaced by the broadband NUWC symbal source panels developed under SWAMSI funding. Also, the nose arrays being built earlyer by NURC is being re-furbished and extensively checked under sub-contract to NURC.

Both MIT AUV configurations are changed by adding a new source section and by mounting nose arrays. Unicorn will have a single nose array while Caribou with the dual array. The new configurations are shown in Fig. 1. The integration of the cymbal source sections is being performed under subcontact to B luefin Robotics, who is also being tasked with re-designing and –furbishing the receiver payloads. Thus, the computer stack is being replaced with a state-of-the-art PC104 stack woith less power requiremenmt, and compatibility with the latest MOOS-IvP autonomy system used for operating the vehicles. Also, the WHOI micromodems used for commanding and controlling the vehicles are being integrated in the payload for compatibility with the MOOS-Ivp control architecture developed under UPS PLUSNet, and under which all future AUV ops with the BF21 s wil be performed. In previous configurations the modem was connected to the main vehicle computer.



array

Figure 1: New Configurations of the MIT BF21 AUVs Unicorn and Caribou. Both are being equipped with a 1-16 kHz cymbal source panel from NUWC, and reconfigured to carry the two 16-element nose arrays built for GOATS by NURC. Also, the receiving payload architecture is being upgraded to be compatible with the current MOOS-IvP autonomy system architecture, complient with thye ASTM F41 proposed standard for AUV command and control.

The new source section consist of a broadband, low frequency acoustic transmitter system known as the cymbal array source. Cymbal modules in Polyurethane gasket is shown in Fig. 2. Figure 3 shows photographs of the finished power electronics within the inner clam-shell designed housing.

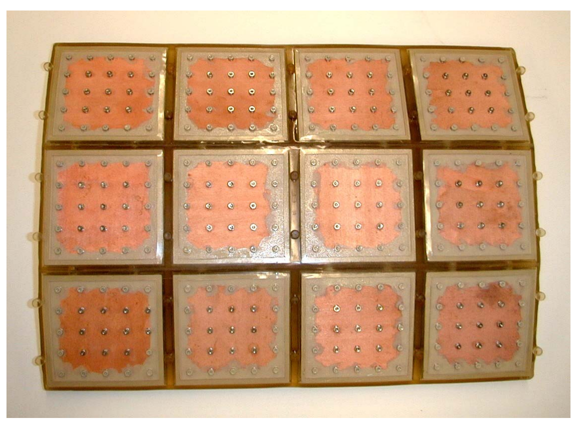


Figure 2: Cymbal Modules in Polyurethane Gasket

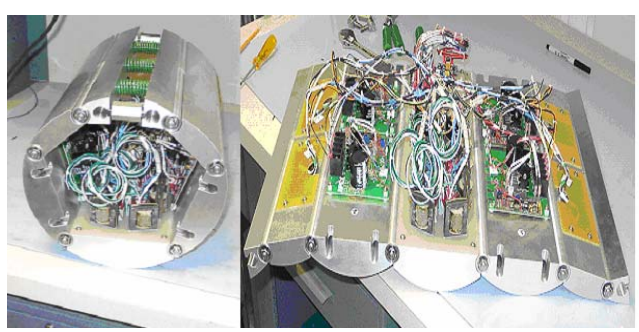


Figure 3: Power Electronics of the Source Section

The cymbal unit will be mounted on a foam as shown in Fig. 4. MOOS payload consist of the electronics to control the acoustic source, a data acquisition system (DAS) to capture acoustic data from the array, an acoustic modem to communicate to the outside world, a CTD sensor for environmental measurements, a computer to run the autonomy of the AUV, and an interface to the main vehicle computer sitting in the tail section. The "back-seat" driver paradigm is used to control the AUV by running the vehicle specific control routines such as safety and low-level controllers in the main vehicle computer (MVC) sitting in the tail section and all the autonomy algorithms in the MOOS computer in the payload section.

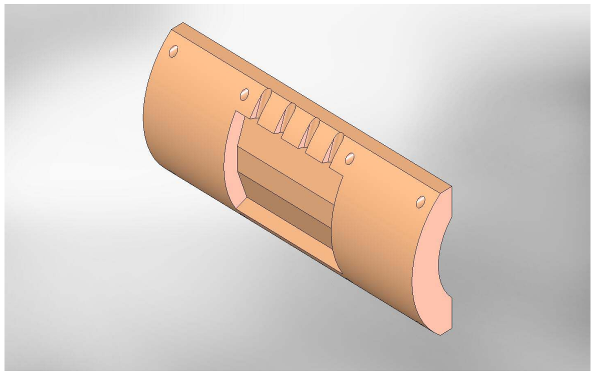


Figure 4: Cymbal Unit Mount on the Foam of the Source Section

RESULTS

The new vehicle configurations will be used in the SWAMSI09 experiment in Panama City, March-April, 2009.

IMPACT/APPLICATIONS

The long-term impact of this effort is the development of new sonar concepts for VSW MCM, which take optimum advantage of mobility, autonomy and adaptivity. For example, bi-static and multi-static, medium-frequency sonar configurations are being explored for completely or partially proud or buried mines in shallow water, with the traditional high-resolution acoustic imaging being replaced by a 3-D acoustic field characterization as a combined detection and classification paradigm, exploring spatial and temporal characteristics which uniquely define the target and its environment.

TRANSITIONS

The virtual source modeling approach developed under this project [4] has been transitioned to NURC as part of the OASE3D target modeling framework. Here it has coupled coupled to the FEMLAB finite element framework to allow modeling of complex elastic targets. It has also been transitioned to NUWC (J. Blottman), CSS (D. Burnett), and WSU (Marston) for the same purpose.

Theffort under this SWAMSI grant was completed in 2008 and the effort has been seamlessly transitioned into the replacement grant, N00014-08-1-0011, the effort in which is described in a separate report.

RELATED PROJECTS

The research effort under this Grant is a seamless continuation of the effort carried out under Grant N00014-04-1-0014. Sharing the underwater vehicles and autonomy system, this effort is closely related to the GOATS project, initiated as the GOATS'2000 Joint Research Project (JRP) with the NATO Undersea Research Centre (NURC). The GOATS effort has been continued at MIT under the GOATS'2005 grant (N00014-05-1-0255), funded jointly by ONR codes 321OA, 321OE, and 321TS. The effort is currently continued under the ONR program GOATS 2008 - Autonomous, Adaptive Multistatic Acoustic Sensing (N00014-08-1-0013) including funding for the collaboration with NURC, which is formally continued under Joint Research Projects (JRP) on multistatic acoustic sensing and surveillance, and undersea distributed sensing networks.

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